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International Perspective on Salinity Gradient Energy

Possibilities and hurdles for further development

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Applications for salinity gradient power plants

1. Open systems (continous operation)

- River and sea water
- Wastewater (e.g. industrial waste water, mining solutions, desalination brine)
- Natural salt resources (e.g. salt lake, salt domes - underground gas storage)
- Hydrothermal solutions (combination with geothermal energy)

2. Closed systems

- Osmotic heat engine (continous operation)
- Osmotic storage plant (batch operation)

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Interesting:

Solutions with a high concentration difference

➡ High osmotic and operation pressure

➡ High specific membrane power

➡ Good economics

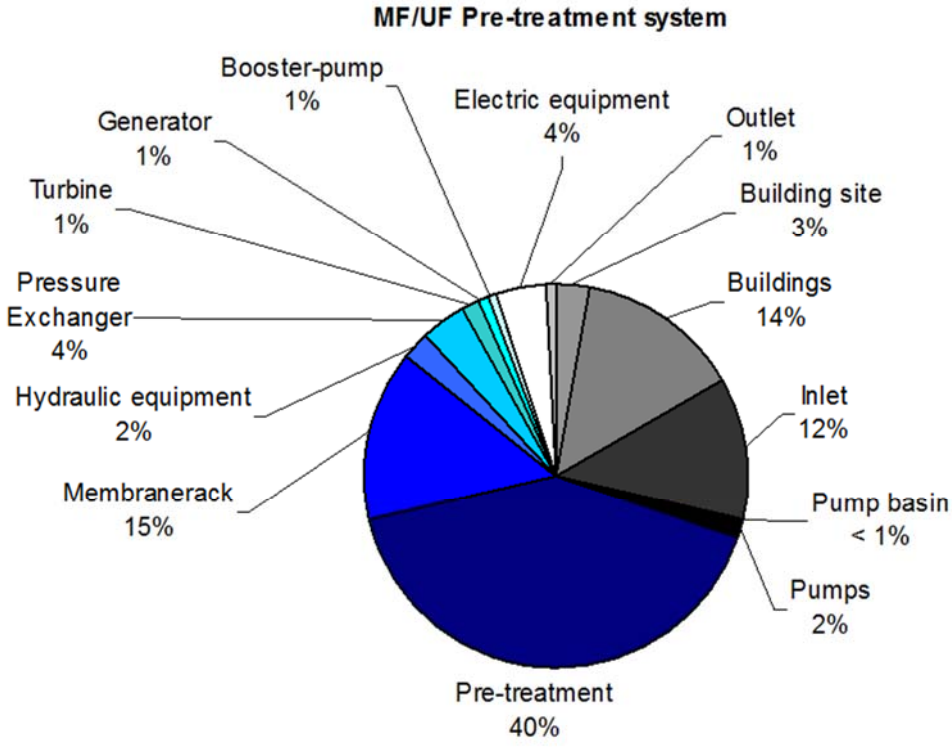
2. Closed systems

- Osmotic heat engine (continous operation)
- Osmotic storage plant (batch operation)

River and sea water

Economic modelling:

Cost share for the components of a PRO plant (1 m³/s, volume flow ratio 1:1) with MF/UF pre-treatment and open intake



Key aspects to reach a reasonable cost range

1. Operation with limited pre-treatment system

➡ Robust membrane modules with a long lifetime required

➡ Membrane development is **more** than optimizing the membrane performance (W/m²)

2. Short water transport system to limit the intake costs

➡ Selection of suitable sites

Wastewater

Industrial waste water and mining solutions (e.g. potash or hardcole mining)

- Legal framework limits the impacts on the river ecosystems

➡ Amount and concentration limits for waste water discharge

- Power plant operation depends on the waste water availability

➡ Difficult (financial) planning (long term availability unclear)

- High concentrated solutions limited to individual cases e.g. potash mining

Top 20 chlorine dischargers in Germany

Company	Location	chlorine load per year	c
Dow Deutschland GmbH & Co. OHG	Stade	1.910.000 t	
K+S KALI GmbH	Philippsthal	1.240.000 t	
Solvay GmbH	Rheinberg	652.000 t	
K+S KALI GmbH	Heringen	574.000 t	
Solvay GmbH	Bernburg	516.000 t	
K+S KALI GmbH	Unterbreizbach	496.000 t	
Emschergenossenschaft	Dinslaken	340.000 t	
Bayer AG/Lanxess AG	Dormagen	320.000 t	
Sodawerk Staßfurt GmbH & Co. KG	Staßfurt	308.000 t	
BASF SE	Ludwigshafen	245.000 t	
RAG Deutsche Steinkohle	Ibbenbüren	205.000 t	
Bayer AG/Lanxess AG	Leverkusen	200.000 t	
RAG Deutsche Steinkohle	Hamm	164.000 t	
Bayer AG/Lanxess AG	Krefeld	120.000 t	
RAG Deutsche Steinkohle	Bottrop	93.800 t	
RAG Deutsche Steinkohle	Gelsenkirchen	78.900 t	
K+S KALI GmbH	Zielitz	77.700 t	
K+S KALI GmbH	Neuhof	71.700 t	
GRACE Manufacturing	Worms	61.600 t	
RAG Deutsche Steinkohle	Duisburg-Walsum	56.100 t	

< 35 g/l

> 100 g/l

Source: PRTR

Desalination

- Operation with desalination brine and ocean water (low concentrated solution) is not applicable

➡ Limited concentration difference and membrane polarisation problems

➡ Solution with low salinity is required – Availability and Applications?!

Natural salt resources

Salt lakes

Great salt lake (Gunnison Bay)

osmot. pressure: 361.6 bar
spec. power: 4.4 MW/(m³/s)
cost: approx. 5 ct/kWh

- High concentrated brine available (100 to > 300 g/l)
- Fresh water availability constricted (site specific)
- Ecology and water management of the salt lake has to be considered

Salt domes / salt caverns

Brine at gas-storage project Jemgum

- Combination with underground gas storage projects possible
- High concentrated brine available (approx. 300 g/l)
- Brine discharge into the ocean to limit environmental impacts
- Brine avilability linked to the production process (fluctuating, no long term availability)
- Brine might contain significant amounts of dissolved solids (depending on geology and feed water quality)
- Possible synergies with existing infrastructure (e.g. inlet, water transport system)

Hydrothermal solutions

- High concentrated solutions available (depending on geology)
  - Neustadt-Glewe: 204 g/l
  - Neuruppin: 200 g/l
  - Bruchsal: 125 g/l

Problems:

- Volume flow increases due to salinity gradient power generation

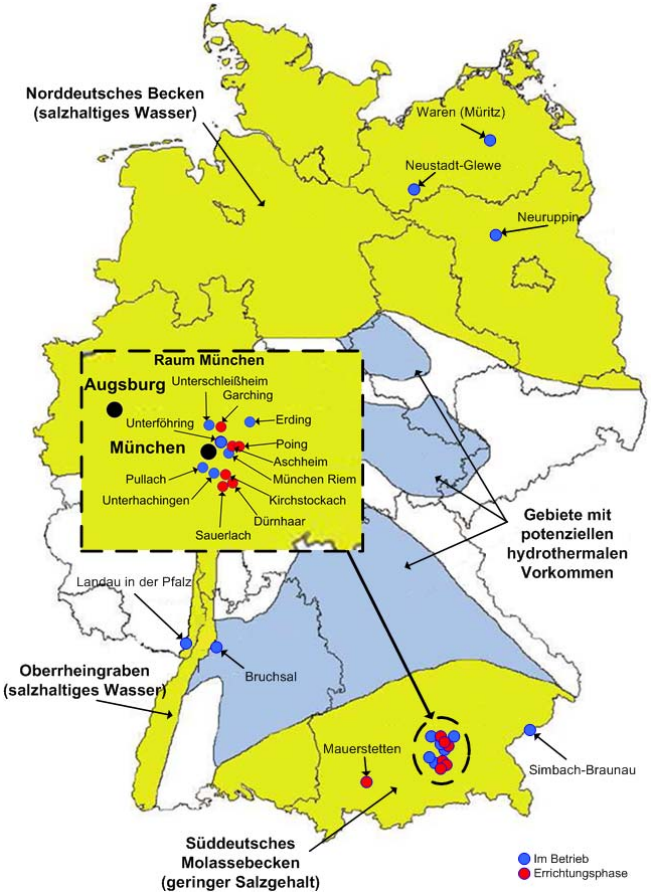
➡ Re-injection and / or disposal of the water mixture problematic

- Degasification of dissolved gases

➡ Controlled degasification and disposal required

- Typically low volume flows (site specific - depending on geology)

Geothermal energy in Germany



Summary - Applications for salinity gradient power plants

1. Open systems (continous operation)

- River and sea water

High potential but limited concentration difference (economics very site specific and depending on further membrane development)

- Wastewater
- Natural salt resources

Limited overall potential but very interesting individual applications existing (high concentrated solutions, good economics expacted, multi-stage concepts possible)

Different, high pressure membranes required?!

- Hydrothermal solutions

Applications unlikely